APPENDIX 3-1

WATER QUALITY MODEL SELECTION TECHNICAL MEMORANDUM

BLACK & VEATCH.

TECHNICAL MEMORANDUM

South Florida Water Management District
EAA Reservoir A-1
Work Order No. 5

B&V Project 141522.320
B&V File:
First Issue: May10, 2005
Last Updated: July 1, 2005

Task 5.3.2.2.1 Model Selection Technical Memorandum
Selection of Water Quality Model

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To: Distribution

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1. BACKGROUND AND OBJECTIVES

1.1 Background

Subtask 5.3.2., Water Quality Model, of Work Order 5, requires Black & Veatch to develop a computer model for predicting pre-impoundment water quality in the EAA A-1 Reservoir. It is important to quantify potential phosphorus levels in the reservoir because all new CERP projects must provide assurances that water quality will not be negatively impacted. High concentrations of phosphorus entering the reservoir from the North New River (NNR) and Miami canals may result in excessive algae growth in the form of floating algae, which could be considered aesthetically undesirable.

As part of the PIR/EIS, the U.S. Army Corps of Engineers (USACE) is currently conducting a water quality assessment of the EAA reservoirs using a water quality model developed by Wetland Solutions, Inc. The model was not considered as an alternative for this study, since it was not available.

1.2 Objectives

The primary objectives of this subtask are to:

- Develop a water quality model that will predict potential levels of phosphorus in water stored in the A-1 Reservoir and in water discharged from the reservoir

- Predict potential excessive algae and low dissolved oxygen concentrations in the reservoir

The purpose of this memorandum is to document the results of Subtask 5.3.2.2, Select Water Quality Model.

2. CANDIDATE MODELS

2.1 Lake Okeechobee Water Quality Model

2.1.1 Description

The Lake Okeechobee Water Quality Model (LOWQM) was developed by the SFWMD to provide an understanding of internal nutrient processing within the lake and to assess lake-wide responses to external nutrient load reductions. The LOWQM is a spatially averaged, deterministic, mass balance model based on an enhanced version of EUTRO5, the eutrophication sub-model of the Water Quality Analysis Simulation Program, Version 5 (WASP5). LOWQM is a "box" model in that it assumes that Lake Okeechobee is completely mixed and is a continuously stirred tank reactor (CSTR).

The original model simulated nitrogen, phosphorus, and dissolved oxygen cycles, as well as phytoplankton dynamics. The LOWQM was enhanced to include the addition of sediment layers and sediment processes that affect nutrient availability in the water column, the impact of sediment re-suspension to the water column, and dynamically changing depths and interfacial areas between water column model segments as the lake volume changes. These improvements are documented in James et al. (1997). The model was further enhanced to include organic phosphorus classes based on degradability and solubility; three algal groups to represent the major algal classes in the lake, including N-fixing cyanobacteria; and silica dynamics to simulate a diatom group.

2.1.2 Application of LOWQM to A-1 Reservoir

LOWQM was calibrated for a period from 1973 to 2000 based on a time series of average daily inflows, outflows, and meteorological conditions for the lake during that period. The following approach would be used to apply LOWQM to the A-1 Reservoir:

- Replace the Lake Okeechobee reservoir volume in LOWQM with the volume of the A-1 Reservoir.
- Import the time series of average daily inflows, releases, and other losses, such as seepage, from the Black & Veatch Water Balance Model (WBM).
- Use LOWQM meteorological data from 1973 to 2000.
- Use existing phosphorus sampling data to estimate phosphorus concentrations associated with A-1 Reservoir inflows.
- Run the modified LOWQM as the A-1 Water Quality Model (A1WQM) continuously from 1973 through 2000. If it is desirable to run the model for a period before 1973, additional meteorological data would be required. However, 1973- 2000 should

encompass a sufficient number of years to account for a wide range of hydrological and meteorological conditions.

The calibration conducted for LOWQM would not be changed for the A-1 Reservoir model unless the model results appear unreasonable. The model would be capable of estimating long-term phosphorus removal in the reservoir as the difference between the phosphorus inflow loadings (mass times concentrations) and the outflow loadings. The model would also be capable of predicting long-term algae and dissolved oxygen concentrations.

2.1.3 Advantages of LOWQM

- Calibrated using a long-term water quality data set.
- Customized to account for physical re-suspension of phosphorus by wind-wave action, which is known to occur in Lake Okeechobee. It is suspected that the shallow A-1 reservoir may be subjected to a similar re-suspension of phosphorus, particularly as the reservoir is drawn down to near zero water volume during its annual cycle of operation.
- Capable of simulating algae.

2.1.4 Disadvantages of LOQWM

- Calibration based on data from only Lake Okeechobee, which has a considerably larger surface area than the A-1 Reservoir. The difference in surface areas may cause the rate of re-suspension of phosphorus from bottom sediments by wind-wave action in the A-1 Reservoir to be significantly different than Lake Okeechobee.
- As a CSTR, model not capable of accounting for potential short-circuiting of inflow and outflows to A-1 Reservoir.
- Does not include capability to simulate downstream STAs.

2.2 DMSTA for Reservoirs

2.2.1 Description

The Dynamic Model for Stormwater Treatment Areas (DMSTA) was developed by Dr. Bill Walker and Dr. Bob Kadlec under contract with the US Department of Interior and the US Army Corps of Engineers to support the design of wetland treatment areas, which would be capable of removing phosphorus from stormwater runoff from the Everglades Agricultural Area and Lake Okeechobee releases. DMSTA simulates daily water and mass balances in a user-defined series of wetland treatment cells, each with specified morphometry, hydraulics, and phosphorus cycling parameters.

Up to six treatment cells can be linked in series and/or parallel to reflect compartmentalization and management to promote specific vegetation types. Each cell is further divided into a series of continuous stirred tank reactors (CSTRs) to reflect residence time distribution.

Water-balance terms for each cell include inflow, bypass, rainfall, evapotransportation, outflow, and seepage in and out of a cell. Parameter estimates for the phosphorus cycling model were developed for various vegetation types.

DSTMA was calibrated to over 100 datasets derived from experimental tanks, field test cells, natural wetlands, operating STAs, wastewater treatment wetlands, and a few lakes north of Lake Okeechobee. Most of these datasets represented relatively shallow marshes dominated by emergent or submerged vegetation. The model is coded in Visual Basic for Applications. The user interface is an Excel workbook.

Compared with typical marsh treatment areas in the Stormwater Treatment Areas (STA), CERP storage reservoir designs, such as the EAA A-1 Reservoir, tend to have greater mean depths, greater variations in depth, and longer water residence times. These factors can be expected to have significant effects on vegetation communities, phosphorus dynamics, and model calibrations. Currently, STAs are operated at a static water depth of 1.2 to 1.5 feet. Deteriorations in vegetation integrity and performance have been observed in cells with prolonged water depths exceeding 2.5 to 3 feet. Current designs for CERP reservoirs have maximum depths ranging from 6 to 12 feet. The expected maximum operating depth for the A-1 Reservoir is 12 feet. The reservoir embankment will be designed to store the Probable Maximum Precipitation and to accommodate wave runup above the 12 foot operating depth.

DMSTA was enhanced by Dr. Bill Walker to support its application to deeper storage reservoirs. DMSTA Version 2 (DMSTA2) and was released in June 2005. DMSTA2 was calibrated and tested using existing datasets from the following sources:

- Burns & McDonnell, Inc. (Under contract to ADA Engineering), "Water Quality Impacts of Reservoirs - Task 3 Analysis of Datasets", prepared for South Florida Water Management District, August 2004. (8 datasets, daily time series)
- Wetland Solutions, Inc. (WSI), "Lake Okeechobee Watershed Project - Calibration of DMSTA Model for Use North of Lake Okeechobee", prepared for HDR, Inc., November 2003. (4 datasets, daily time series)
- W.W. Walker, "Estimation of a Phosphorus TMDL for Lake Okeechobee, prepared for Florida Dept of Environmental Protection & U.S. Department of the Interior, December 2000. (2 datasets, monthly time series)
- W.W. Walker & K. Havens, "Development & Application of a Phosphorus Balance Model for Lake Istokpoga, Florida", Lake & Reservoir Management, Vol. 19, No 1, pp. 79-91, 2003. (1 dataset, daily time series)
- USEPA., "A Compendium of Lake & Reservoir Data Collected by the National Eutrophication Survey in Eastern, North-Central, & Southwestern United States", Working Paper No. 475, Corvallis Environmental Research Lab and Environmental Monitoring & Support Lab, Las Vegas, September 1978. (28 Florida lakes sampled in 1973, for testing of steady-state model)

2.2.2 Application DMSTA2 to A-1 Reservoir

In general, the approach to applying DMSTA2 to the A-1 Reservoir is similar to the approach for applying LOWQM discussed in Section 2.1.2:

- Time series of inflows and outflows to the A-1 Reservoir would be imported from the WBM.

- Time series of phosphorus concentrations associated with the North New River and the Miami canals will be based on monthly average concentrations developed by Burns & McDonnell (Under contract to ADA Engineering) as part of the Regional Feasibility Study, Task 1.3, Historical Inflow Volumes and Total Phosphorus Concentrations by Source, June 27, 2005.
- The A-1 Reservoir model based on DMSTA2 would be capable of continuous predictions of phosphorus concentrations in the reservoir and in the reservoir releases over a long-term simulation period.

2.2.3 Advantages of DMSTA2

- Calibration is based on multiple Florida lakes.
- Capable of predicting phosphorus removal by uptake of phytoplankton
- Capable of predicting the re-suspension of phosphorus from the bottom sediments to the extent that this process occurs in shallow Florida lakes.
- Capable of simulating reservoirs linked to downstream STAs.

2.2.4 Disadvantages of DMSTA2

- Does not simulate phytoplankton or macrophyte biomass – only the phosphorus uptake associated with the growth of phytoplankton and macrophytes.
- As a CSTR, model not capable of accounting for potential short-circuiting of inflow and outflows to A-1 Reservoir.

2.3 CE-QUAL-W2

2.3.1 Description

CE-QUAL-W2 is a two-dimensional (longitudinal-vertical) hydrodynamic and water quality model for reservoirs. The model is capable of continuously simulating the basic eutrophication processes, such as temperature-nutrient-algae-dissolved oxygen-organic matter and sediment relationships in thermally stratified and non-stratified systems. The model is supported by the Corps of Engineers, Waterways Experiments Station in Vicksburg, Mississippi. The water quality algorithms incorporate 21 constituents, including temperature, species of nitrogen and phosphorus, phytoplankton, and dissolved oxygen (DO), including interactions during anoxic conditions.

2.3.2 Application of CE-QUAL-W2 to A-1 Reservoir

In general, the approach to applying CE-QUAL-W2 to the A-1 Reservoir is similar to the approach for applying LOWQM discussed in Section 2.1.2:

- Time series of inflows and outflows to the A-1 Reservoir would be imported from WBM.
- Phosphorus concentrations associated with the time series of inflows would be based on existing sampling data.

- To the extent possible, CE-QUAL-W2 would be calibrated based on similar calibration coefficients taken from LOWQM. Calibration coefficients not available from LOQWM would be based on literature values and Black & Veatch experience from other applications of the model.
- The A-1 Reservoir model based on CE-QUAL-W2 would be capable of continuous predictions of phosphorus concentrations in the reservoir and in the reservoir releases over a long-term simulation period.

2.3.3 Advantages of CE-QUAL-W2

- Capable of predicting water quality in two dimensions: horizontally (laterally averaged) and vertically in the water column. The horizontal dimension allows a spatial distribution of water quality caused by flow inputs and withdrawals at different locations in the reservoir.
- This two-dimensional, laterally averaged model is capable of accounting for potential short-circuiting of inflow and outflows to A-1 Reservoir if the inflows and outflows are not located in the same laterally averaged model cell.

2.3.4 Disadvantages of CE-QUAL-W2

- Calibrated for only one Florida reservoir. This was Tampa Bay Water's new surface supply, which is relatively deep compared to the A-1 Reservoir.
- Does not account for possible re-suspension of phosphorus from bottom sediments due to wind-wave action.
- Does not include capability to simulate downstream STAs.

3. CONCLUSIONS

DMSTA2 applied to the A-1 Reservoir is expected to provide the most accurate estimate of long-term phosphorus removal in the reservoir because the model has been calibrated to numerous Florida reservoirs; the model is capable of predicting the re-suspension of phosphorus from the bottom sediments; and the A-1 model releases can be input directly to the STA 3-4 DMSTA2 model. Therefore, DMSTA2 was selected for use in the A-1 Reservoir.

The LOQWM has the ability to directly account for the re-suspension of phosphorus from the bottom sediments due to wave-wind action. However, the model was calibrated using a data set from Lake Okeechobee only, which is considerably larger and somewhat deeper than the A-1 Reservoir. LOWQM may over estimate phosphorus removal, because Lake Okeechobee does not experience the severe draw down that will occur in the A-1 Reservoir.

Predictions of phosphorus removal by CE-QUAL-W2 applied to the A-1 Reservoir are expected to be the least accurate because the model was calibrated to only one deeper reservoir in Tampa, Florida. Although some of the calibration coefficients from LOWQM could be applied to CE-QUAL-W2, there are a number of coefficients that would have to be estimated based on model applications in reservoirs not located in Florida. The capability of the model to simulate a spatial distribution of water quality is not considered a significant advantage: Since water will normally be pumped into the reservoir during the rainy season of June – November and released to meet environmental and irrigation demands throughout the year, there is only a slight chance for short-circuiting inflow to outflow. The potential for short-circuiting will be dependent on the reservoir configuration and location of the pump stations and discharge structures, which will be considered under separate work orders.

4. REFERENCE

James, R. T., J. Martin, T. Wool, and P. F. Wang. 1997. A Sediment Resuspension and Water Quality Model of Lake Okeechobee. Journal of the American Water Resources Association 33:661-680